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Date: July 31, 1996

Subject: Evaluation of conifer mortality in the Loyalton Pines area (Report # NE 96-11)

To: District Ranger, Sierraville Ranger District, Tahoe National Forest

At the request of Ralph Meinel, I conducted a field evaluation of the National Forest land immediately south of the Loyalton Pines area on July 11, 1996. The objective of the evaluation was to determine what agents were involved with the conifer mortality and provide management alternatives for forest health restoration and maintenance.

Areas examined included Sections 21, 22 and 23 in T 21N. R 15E (See attached map). Loyalton Pines is a small community located adjacent to the National Forest boundary. Most homes are situated in a forested setting with the primary vegetation being comprised of Jeffrey and ponderosa pine trees.

Existing Condition

Species composition in the stands adjacent to Loyalton Pines is dominated in terms of space occupied and crown position by ponderosa and Jeffrey pine. Trees are typically less than 20"dbh. The understory has the same mix of pine species with a minor component of white fir and incense cedar. As elevation increases to the south of Loyalton Pines towards Loyalton Mountain the species composition becomes more dominated by white fir. Basal areas in the pine stands range from about 170-230+ square feet/per acre.

Current and older conifer mortality exists throughout the area (See attached map). This can be attributed to bark and engraver beetle activity, below normal precipitation for several years and overstocking. There has been an increase in mortality in the pine species over the past 5 years. The majority of the older mortality (no needle retention) has been blown down resulting in a considerable increase in fuels. Current pine mortality is apparent as three to ten tree group kills in trees <10" dbh in Sections 22 and 23 and as individual, larger,scattered pine trees in Section 23. Bark beetles involved include western pine beetle in the ponderosa pine and Jeffrey pine beetle in the Jeffrey pine. Red turpentine beetle pitch tubes are present at the base of some pine trees, however, it is not likely that these beetles are playing a significant role in tree mortality. There is both old and current white fir mortality throughout the area which can be attributed to fir engraver beetle activity, drought, and overstocking.

Drought and Bark Beetles

Historically, the most significant widespread, weather-related effect on the vegetation in California has been conifer mortality associated with severe moisture stress. Conifer mortality tends to increase whenever winter precipitation is less than about 80% of normal. Trees stressed by inadequate moisture levels have their normal defense systems weakened to the point that they are highly susceptible to attack by bark, engraver and wood-boring beetles. Drought conditions have been recorded 9 times for the Sierra Cascade zone since 1985 (See Fig. 1).

Bark and engraver beetle-related mortality occurs primarily in small groups with the pine bark beetles or as single trees scattered over several hundred acres with the fir engraver. Successful attacks by the pine bark beetles (western, mountain and Jeffrey pine beetles) result in tree mortality. Successful attacks by the fir engraver (in red and white fir) can result in top-kill, branch kill, patch kills along the bole and/or whole tree mortality (See attached information). In general, mortality occurs in overstocked stands, however during periods of protracted drought, mortality may be expected to occur throughout various stocking regimes. Effects resulting from bark beetles may include the following: direct tree mortality, openings that vary in size, less trees/acre, reduced canopy closure, increase in standing dead and down woody material, increase in fuel load, increase in decomposition and nutrient cycling, increase species diversity/decrease species diversity, increase in snags and cavity nesting opportunities and a change in species composition.

The importance or significance of these effects depends on their severity and extent and ultimately how they affect (positively and/or negatively) ecosystem structure and function (desired condition) and specific management goals and objectives. The effects of insects and pathogens can be used as an indicator of forest and ecosystem health.

Mortality Outlook (1-2 years)

Experience from the 1975-77 drought indicates that surviving trees can regain their vigor relatively quickly after precipitation and soil moisture levels return to normal. The recent drought lasted much longer and it is likely the surviving trees may take longer to recover than during the 1970's drought period. In general, conifer mortality levels have decreased over the past 2 years compared to levels experienced in the early 1990's. White fir mortality has decreased in most eastside areas, however, Jeffrey pine mortality has actually increased over the past 2 years in some locations on the eastside. The decrease in white fir mortality is likely the result of several factors including the increase in precipitation over the past two years and lower stocking levels (as a result of the mortality).

The new mortality (both pine and some white fir) that is currently visible in the Loyalton area is the result of bark and engraver beetle attacks last year, therefore, I would not expect to see any decrease in fading trees or mortality this year. It appears that the white fir mortality is decreasing in the analysis area and will likely continue to do so. The level of current (fading this year) Jeffrey and ponderosa pine mortality appears to be about the same as last year. There were several trees that were unsuccessfully attacked last year indicating that the trees had enough moisture to "pitch" the beetle out.

the trees, similar to other management activities.

Thinning is perhaps the most critical silvicultural treatment available to restore and maintain forest health. Thinning from below reduces flammable fuels, and creates growing space for trees. There are several natural and regenerated stands that are currently carrying more than the sites can support. Silvicultural prescriptions designed to reduce basal area, select against off-site tree species and remove dwarf mistletoe infested trees,, should result in lower levels of bark beetle-related mortality in the future. Reduced mortality would also have the effect of a reduction in the occurrence of understocked stands that would have low canopy closure. Mortality would continue to occur and fluctuate in response to the amount of available moisture, but at levels that, through time, would more closely approximate naturally occurring mortality levels. Thinning would result in: a decrease in the need to enter stands to conduct salvage operations, a decrease in the amount of fuel loading (Snags and down woody material would occur at more natural levels) and a reduction in the number of hazard trees.

Snags, down woody material and nutrient cycling would occur at more natural levels. The improved growing conditions should result in reduced mortality of large diameter trees and an increase in mid-diameter trees available to grow into large diameter classes. Selecting for diversity of residual tree species during thinning is desired as bark beetles are fairly host-specific and diversity should guarantee that some trees will remain alive during elevated stress periods. Removing competing vegetation from plantations will reduce the susceptibility to various insects which often cause damage to regeneration. Dependent upon slash treatment, there would be some level of risk of subsequent top-kill and/or whole tree mortality to residual conifers due to pine engravers that reproduce in green slash. This risk would be considered to be lower in the range of Ips pini and somewhat higher in the range of Ips paraconfusus.

When harvesting conifers it is important to treat the freshly cut stump surfaces with a registered borate compound to prevent stump surface colonization by annosus root disease.

Thinning Guidelines for Eastside Pine

In terms of reducing bark beetle-related mortality to acceptable levels, information obtained from three thinning studies in east side pine stands provide some general guidelines that can be used when writing silvicultural prescriptions.

Poison Lake Study - Gary Fiddler, PSW

In 1978-1979 the Forest Service established plots in the eastside pine type to show the effects of thinning on pest-caused losses in areas of high tree mortality. The stands chosen were mostly pole-size ponderosa pine mixed with some white fir and incense-cedar, growing on medium to low sites, and ranging in age from 70 to 90 years. Within the demonstration plots, four levels of stocking density -- 40, 55, 70, and 100 percent of normal basal area -- were established to demonstrate the biological and economic alternatives available for management planning. (Normal basal area is the basal area that a stand should have reached when fully stocked with trees, which in the demonstration areas, ranges from 185 to 215 sq. ft./ac.,

Although bark beetle population levels are difficult to estimate, it can be concluded that there are more bark beetles present now than before the substantial increase in pine mortality. Even with the increase in precipitation over the past two years, mortality will likely continue at unacceptable levels in the Loyalton Pines and National Forest interface until the stocking level is reduced to that appropriate for the site.

Management Alternatives

The following may be used to develop management alternatives leading in the direction of a desired future condition.

(1) No action - Overstocked stands in general will tend to have higher levels of bark and engraver beetle-related mortality. The recent protracted drought period has brought attention to both the high level of pine and white fir mortality and the existing fire hazard now present in the eastside type. With no management, the areas of extreme mortality present a fire hazard. The basal areas in stands will continue to increase as the trees grow. Periodic droughts in California increase the probability that some of the trees in overstocked stands will be attacked by bark beetles. Although some mortality may be desired for snags, small openings and for future down woody debris, the no action alternative will most likely result in unacceptable levels of mortality. On the eastside, particularly in understocked stands, a reduction in canopy closure and openings that range from less that 1/4 acres to 50 acres or more should be anticipated in areas where no management activities take place. As a result of the recent drought period, there are openings greater than 50 acres on the eastside particularly in areas dominated by white fir. Mortality levels will typically be above background levels as stand density increases, and this affect will be accentuated during periods of below normal precipitation.

The direct result of an increase in tree mortality is the increase of standing dead (snags) and down woody material. This may result in: a continuing desire to enter stands to conduct salvage operations, an increase in fuel loading, fewer large, older trees and fewer of the mid-diameter trees that represent the pool from which the large trees and snags of the future come from, a short term increase in nutrient cycling and an increase in the number of hazard trees (dependent upon location, ie. campgrounds, along roads).

(2) Salvage - Salvage sales can minimize the economic loss and reduce the amount of dead fuel, however, these operations will have no effect in reducing or controlling bark beetle populations. At the present time, there are no biologically effective or economically efficient methods available to reduce bark beetle populations on an area-wide basis such that tree mortality will be reduced to acceptable levels. As a general rule, during periods of above normal tree stress, it is recommended that logging, thinning and timber stand improvement work be minimized as much as possible to reduce the potential for additional stress. Where such activities must occur, extra care should be taken to prevent damage to residual trees.

(3) Thinning Overstocked Stands - Management activities that promote tree health and vigor also reduce the susceptibility of successful bark beetle attack. However, increased tree health and vigor will not be an immediate response. In the short term, thinning stands places an additional stress on

depending on site quality.) Fourteen years after thinning, the treatments had reduced mortality from 90 to 100 percent of the level in unthinned stands.

COMMERCIAL TREE MORTALITY BY STOCKING LEVEL, TWELVE YEARS AFTER THINNING[a]

Year	Residual Stocking After Thinning[b] 40%	55%	70%	100%
		Trees per Acre		
1980	0.0	0.2	0.2	2.4
1981	0.0	0.0	0.7	2.4
1982	0.0	0.5	0.3	3.6
1983	0.0	0.1	0.8	4.1
1984	0.0	0.0	0.0	1.0
1985	0.0	0.2	0.0	0.6
1986	0.0	0.0	0.0	1.3
1987	0.0	0.0	0.0	1.4
1988	0.0	0.0	0.0	0.0
1989	0.0	0.4	0.0	2.6
1990	0.0	0.0	0.0	2.6
1991	0.0	0.0	0.0	1.8
1992	0.0	0.2	0.0	3.0
1993	0.0	0.2	0.3	5.2
1994	0.0	0.0	0.0	4.8
1995	0.0	0.0	0.3	0.4
Mean	0.0	0.1	0.2	2.3
Range	0	0-0.5	0-0.8	0.0-5.2
Percent Mortality Reduction Compared with Normal Basal Area	**100**	**95.7**	**91.3**	**---**

[a] Commercial trees are 8 inches dbh and larger, with straight boles, yielding at least one 10-foot log with a 6-inch top. Trees were killed by the mountain pine beetle.

[b] Percent of normal basal area.

Sugarhill Study - William W. Oliver, PSW

Four growing stock levels are under test in the extensive plantations at Sugar Hill in the Warner Mountains east of the Sierra Cascade crest (Oliver 1979a). The study was initiated in 1959 when the plantation was 28 years old. Four unreplicated plots were thinned to stand density indices (SDI) of 25, 50, 128 and the unthinned control of 157. In the unthinned plot, when the SDI reached 327 mountain pine beetle began killing large numbers of trees. Half of the trees were dead by 1995 reducing the SDI to 264. Mortality began in the plot thinned to 128 SDI when its SDI reached 331. By 1995 beetles had killed 23% of the trees, reducing SDI to 291. Based on this data, the limiting SDI for ponderosa pine stands in northern California is 365. SDI 230 defines the threshold for a zone of imminent bark beetle mortality within which endemic populations kill a few trees but net growth is still positive.

(4) Insect Suppression/Prevention

Insect Suppression

Insect suppression that may be applicable to the analysis area is the removal of Jeffrey pine trees prior to beetle emergence. This may be most practical in areas where individual trees have high value and infested trees can be identified while the tree crown are still green and the beetles are still in the tree. Removal of infested trees can be completed over larger acreages as well if the effort is made to identify green infested trees on an annual basis until mortality levels decline. Tree removal, in most cases would need to be complete by May or June, dependent on temperature and beetle development.

Circumstantially successful Jeffrey pine beetle suppression projects have been conducted in the Lake Tahoe Basin Management Unit since the mid-1980's. Infested pine trees were removed on an annual basis for 4 consecutive years (1983-1987) on 165 acres. Mortality in the treated area declined from 330 trees in 1983 to 4 trees in 1987. Reduced mortality is also apparent in the Zephyr Cove Resort and Nevada Beach Campground as a result of annual suppression efforts initiated in 1993.

Prevention - There are registered insecticides for pine bark beetle prevention that are effective in preventing bark beetle attacks. This is a prevention treatment, in that the insecticide needs to be applied prior to a tree becoming infested with bark beetles. If a tree is already infested, this treatment would not be successful in saving the tree. Typically this treatment has been used for high value trees such as those in campgrounds or around administrative sites or for protecting identified rust resistant sugar pine trees.

Conclusion

Forest health restoration activities should take an ecological approach to multiple-use management. Objectives for this area might include restoring the resistance and resilience to natural stresses, decreasing the risk of catastrophic fires, modifying the vegetation to reduce potential damages caused

by insects and disease. Treatments in this area now can reduce risk and change the impact of disturbances such as wildfire and insects so that they more closely resemble the norm in intensity and effect.

If you have any questions regarding this evaluation or need additional assistance please call me at 916-257-2151 ext. 6667.

Sheri Lee Smith
Entomologist
NE CA Shared Service Area

Bark Beetle Information by Host Tree

White fir

White fir dominates many areas on the eastside that were once dominated by pine species. Fire exclusion and selection harvesting practices have caused a continued shift away from shade-intolerant pine species toward more shade tolerant white fir. White fir is a more short lived species and does not tolerate extended periods of moisture stress compared to ponderosa or Jeffrey pine.

Fir Engraver

The fir engraver, Scolytus ventralis, is the most important bark beetle attacking red and white fir in California. It attacks and can kill nearly all age classes. Host species for the fir engraver range throughout much of the analysis area. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and otter sapwood of the bole, thereby girdling the tree. Trees greater that 4 in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without first killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem of, usually in areas that are greater than 4 inches in diameter. Reddish-brown or white boring dust may be seen along the truck in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks however true firs are known to pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that come contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes that are often formed when bark beetles attack pine are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part of all of the bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters

the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry a brown staining fungi, Trichosporium symbioticum, into the tree which causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

There does not seem to be a recognizable pattern of fir engraver outbreaks in California. When outbreaks do occur their simultaneous occurrence in many widely separated localities, causes severe damage to forests. Sporadic outbreaks have been recorded in California and Oregon at least once a decade since 1925. Dry sites, drought and root disease play important roles in the susceptibility of true fir to fir engraver, and they are probably the most important factor influencing the food supply for beetles. Under adequate moisture regimes, overstocking of fir stands and high infection rates by root disease are the principal factors involved in predisposing trees to attack by fir engraver.

A rapid buildup of fir engraver populations to epidemic levels is indicative of other conditions which promote substantial increases in food supplies, such as can occur when large number of trees are weakened by catastrophic events. It appears that where white fir is growing at lower elevations and on drier sites that outbreaks in northeastern California cycle with drought periods. Fir engraver-related mortality increased dramatically during 1977-78 coinciding with below normal precipitation in northern California. Stress associated with protracted drought periods is probably the most critical factor in determining outbreaks in California. Based on annual salvage volumes obtained during previous drought periods, it appears as through fir-engraver mortality decreases rapidly when moisture conditions return to normal. Moisture stress accumulated over several years of drought may require a longer period of time for tree recovery and reduced mortality levels.

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those which have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality however attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Ponderosa pine

Ponderosa pine mortality has been increasing in the area for about the past five years. The significant increase in ponderosa pine mortality can be

attributed to moisture stress, overstocking in some cases and elevated bark beetle activity. Current and older group kills are common just south of Loyalton Pines. Mortality of single large DBH ponderosa pine are also common on some of the ridges. Western pine beetle is associated with the mortality.

Western pine beetle

The western pine beetle, Dendroctonus brevicomis, has been intensively studies and has proven to be an important factor in the ecology and management of ponderosa pine throughout the range of this host species. This insect breeds in the main bole of living ponderosa pine larger than about 4 inches dbh. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latitude and elevation, there can be from one to four generations per year.

Evidence of Attack

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes, formed on the tree trunk around the entry holes made by the attacking females. The pitch tubes are red-brown masses of resin and boring dust. Relatively few, widely scattered, white pitch tubes usually indicate that the attacks were not successful and that the tree will survive. Pheromones released during a successful attack attract other western pine beetles. Attacking beetles may spill over onto nearby apparently healthy trees and overwhelm them by sheer numbers.

Life Stages and Development

These beetles pass through the egg, larval, pupal and adult stages during a life-cycle that varies in length dependent primarily upon temperature. Adults bore a sinuous gallery pattern in the cambium and the female lays eggs in niches along the sides. The larvae are small white grubs that first feed in the phloem and then mine into the middle bark where they complete most of their development. Bluestain fungi introduced during successful attacks probably contribute to the rapid mortality associated with bark beetle attacks.

Conditions Affecting Outbreaks

Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the West since 1899. An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles. Information from surveys initiated in the 1930s indicates that there were enormous losses attributed to western pine beetle around that time. During this outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor.

Under normal conditions the western pine beetle breeds in a few overmature trees, unhealthy trees, or in trees weakened by drought, stand conditions, or fires. The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing outbreaks in that

healthy trees undergo sudden and severe moisture stress are key to buildup of western pine beetle populations. The thick, nutritious phloem and inner bark of healthy trees become host material for attacking beetles when these trees undergo sudden and severe moisture stress. Healthy trees ordinarily produce abundant amounts of resin, which pitch out or eject attacking beetles. But, when deprived of moisture, stressed trees cannot produce sufficient resin flow to resist attack. Any condition that results in excessive demand for moisture, such as tree crowding, competing vegetation or protracted drought periods; or any condition that reduces that ability of the roots to supply water to the tree, such as mechanical damage, root disease, or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers, predaceous beetles and low winter temperatures cause natural control.

Mountain pine beetle

The mountain pine beetle, Dendroctonus ponderosae attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 8 inches dbh. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

Evidence of Attack

The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. Pitch tubes on successfully infested trees are pink to dark red masses of resin mixed with boring dust. Creamy, white pitch tubes indicate that the tree was able to "pitch out" the beetle and the attack was not successful. Besides having pitch tubes, successfully infested trees will have dry boring dust in the bark crevices and around the base of the tree. Infested trees can also have boring dust, but not pitch tubes. This may be common in drought years when trees produce little pitch. Attacking beetles carry with them the spores of blue-staining fungi. As the fungi develop and spread throughout the sapwood, they interrupt the flow of water to the crown. The fungi also reduces the flow of pitch in the tree, thus aiding the beetles in overcoming the tree. The combined action of both beetles and fungi causes the tree to die and the needles to discolor.

Life Stages and Development

The beetle develops through four stages: egg, larva, pupa and adult. The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is the general rule, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine. Females making their first attacks release aggregating pheromones. These pheromones attract males and other females until a mass attack overcomes the tree. The adults bore long vertical egg galleries and lay eggs in niches along the sides of the gallery. The hatching larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

Conditions Affecting Outbreaks

The food supply regulates populations of the beetle. In lodgepole pine, it appears that the beetles select larger trees with think phloem, however the relationship between beetle populations and phloem thickness in other hosts has not been established. A copious pitch flow from the pines can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include low winter temperatures, nematodes, woodpeckers and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and mortality increases.

Jeffrey pine

Above normal levels of Jeffrey pine mortality have been observed have been observed on the eastside of the Sierra Nevada range since about 1990. This mortality is associated with successful attacks of the Jeffrey pine beetle, protracted drought, and overstocking in some cases. It appears that the majority of the Jeffrey pine beetle-related mortality has occurred within the past 2-3 years. This mortality is predominantly on the Truckee, Sierraville, and Milford Ranger Districts. Some mortality is also present on the Eagle Lake RD. From north (Eagle Lake RD) to south (Truckee RD) on the east side the level of Jeffrey pine mortality decreases. Large groups of trees and scattered, large, single DBH individual trees faded this year (1996) as a result of attacks during 1995.

Jeffrey pine beetle

Jeffrey pine beetle, Dendroctonus jeffreyi is the principle bark beetle found attacking Jeffrey pine, which is its only host. It is a native insect occurring from southwestern Oregon southward through California and western Nevada to northern Mexico. The beetle normally breeds in slow-growing, stressed trees. The beetles prefer trees which are large, mature, and occur singly rather than in groups. Yet when an epidemic occurs, the beetle may attack and kill trees greater than 8 inches in diameter, regardless of age or vigor. Often the beetle infests lightning-struck or wind-thrown trees, but does not breed in slash.

Evidence of Attack

Presence of the beetle is usually detected when the foliage changes color. The color change of the foliage is related to the destruction of the cambium layer by the beetle. Generally, the top of the crown begins to fade in a slow sequence, with the needles turning from greenish yellow, to sorrel, and finally to reddish brown. By the time the tree is reddish brown, the beetles have usually abandoned the tree. Another sign of beetle attack is large, reddish pitch tubes projecting from the bark of the infested tree. If examined carefully, pitch tubes can be detected on infested green trees prior to crown fade. Jeffrey pine beetles have a distinctive "J" shape egg gallery pattern on the inner bark. Larval mines

extend across the grain and end in open, oval-shaped pupal cells.

Life Stages and Development

The Jeffrey pine beetle is one of the larger pine bark beetles in California. The beetle has a 4 life stages, egg, larva, pupa, and adult. The adults are stout, cylindrical, black, and approximately five-sixteenths of an inch long when mature. The egg is oval and pearly-white. The larva is white, legless, and has a yellow head. The pupa is also white but is slightly smaller than the mature larva. The life cycle is normally completed in one year in the northern part of the range, but in the southern part, two generations per year may occur. The principle period of attack is in June and July, but attacks also are frequent in late September and early October. Similar to other Dendroctonus species, Jeffrey pine beetles use pheromones that attract other beetles to a tree, causing a mass attack that tends to overcome the tree's natural resistance. Bluestain fungi are associated with Jeffrey pine beetle attacks and aid in overcoming the tree.

Conditions Affecting Outbreaks

Normally the Jeffrey pine beetle is kept in check by its natural enemies, climatic factors, and the resistance of its host. Similar to other Dendroctonus species, the availability of suitable host material is a key factor influencing outbreaks. Healthy trees ordinarily produce abundant amounts of resin, which pitches out attacking beetles. When deprived of moisture, trees cannot produce sufficient resin flow and they become susceptible to successful beetle attacks.

- Pine Mortality
- Fir Mortality
- Scattered Fir Mortality
- Scattered Pine and Fir Mortality

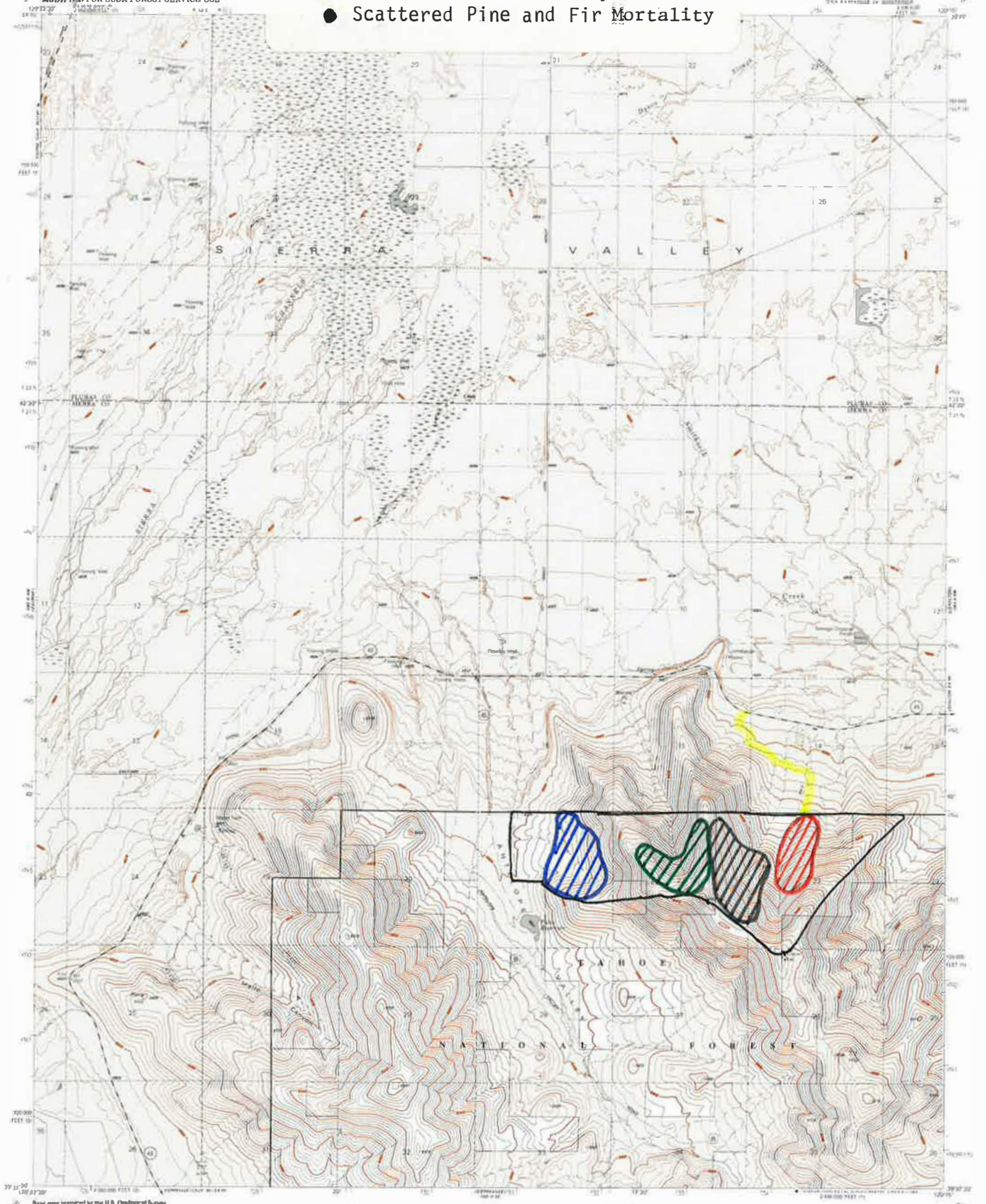

Figure 1.

Sierra Cascade

Palmer Drought Index